difficult to demonstrate. That is to say, the work of the dietitian may have little or no obvious influence upon the incidence of abnormalities such as stillbirth, premature birth, and even pre-eclampsia. Nevertheless, dietary education has a useful place in the management of nausea and vomiting, heartburn, constipation, obesity and oedema; and its most important benefits may be felt in the future, if, as a result of dietary teaching, the mother of today feeds her children better and thus helps to produce a better-grown, healthier, and better-informed next generation.

The values in Table 1 have been taken from an unpublished analysis of the Aberdeen data by Miss E. B. Hope, Miss J. W. Marr and Miss J. D. Stevenson, to whom I wish to express my thanks.

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Flavour and flavour acceptance

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In this paper the subject is treated in three sections, namely the physiology and the chemistry of flavour, and the methods used by tasting panels.

Physiology

Flavour involves principally the three senses—touch, taste and smell. Appearance of food is also important, as was found in our experiments with battery and 'free-run' eggs. The free-run eggs have usually a deeper colour and a slightly stronger texture, due to a stronger, thicker white. When organoleptic tests were performed with a panel blind-folded, flavour comparisons showed little difference between the eggs. However, highly significant results were obtained in favour of the free-run eggs when the panel were allowed to see the product, as scrambled eggs or as custards, sponges and cakes.

Sound may also be part of flavour acceptance. The sound of a breaking biscuit or shortbread, the crunch of toffee and of a hard apple have all a definite appeal.

https://doi.org/10.1079/PNS19610011 Published online by Cambridge University Press

Taste is due to the gustatory cells in the taste buds of the fungiform and circumvallate papillae of the tongue. Each gustatory cell has several fine processes which pass through the taste-bud pore and are bathed in the salivary solutes. The flavorous substance does not penetrate the gustatory cell (Kimura & Beidler, 1956), but is weakly adsorbed on the taste hair. This adsorption causes a rearrangement of the large molecules and a depolarization of the surface of the taste cell which spreads downwards to stimulate the gustatory nerve fibre. The frequencies of the electrical impulses discharged by the sensory end-organ seem directly proportional to the strength of the stimulus (Beidler, 1953). These nerve fibres convey impulses to the hypothalamus and other parts of the brain. They have no connexion with the autonomic system (Crocker, 1945). Reflex excitation of the salivary and gastric glands occurs in response to taste. Animals are more sensitive to taste than man.

The taste buds register sweetness, sourness, saltiness and bitterness, but not the characteristic flavours of coffee, fruit, wines and onions. The tip of the tongue registers sweetness, the sides and the tip saltiness, the sides sourness, and the back bitterness.

Sensitivity varies from one gustatory cell to another, some responding to acid and salt and others to acid, salt and sugar (Fishman, 1957; Pfaffmann, 1955). Single nerve fibres may innervate several gustatory cells. A slight change in structure of the stimulating substance may produce different sensations, e.g. *p*-ethoxyphenylthiourea is bitter but *p*-ethoxyphenylurea is very sweet. Genetic factors control the response to particular flavours, and inter-species differences are greater than within-species.

Sensitivity to sweetness develops first, and so extremely young children show a preference for sugar. With age the fungiform papillae decrease in numbers and the circumvallate papillae at the base of the tongue become more important. There is a slight decline in taste sensation after 45 but a considerable decrease after 70 (Arey, Tremaine & Monzingo, 1935). The response of sensory gustatory cells decreases considerably in the first few seconds after stimulation and afterwards gradually declines which is important to chefs, who tend to over-flavour in consequence. A cook seldom enjoys his or her own cooking. A highly flavoured hors d'oeuvre should not be served at the beginning of a meal followed by a delicately flavoured entrée: appreciation of the latter will be lost. Poorly flavoured cheaper wines should be served early in a meal and the well-flavoured varieties at the end. The bitterness of grapefruit is only obvious as an after-taste. This sensation is registered by the circumvallate papillae where the taste buds are in deep clefts into which flavorous substances take longer to penetrate.

Cold and heat can paralyse the taste receptors. Russian tea with lemon has no sour taste when hot. Ice-cream must be very sweet to taste sweet. Substances must be in solution to reach the taste buds. Fruit jellies are incompletely dissolved in the mouth and must therefore be highly flavoured. The same applies to foods in aspic. Flavours of foods are released by chewing. Breakdown of the cells liberates enzymes which produce flavours by acting on potential flavour precursors.

The smell contributes to the flavour of food. For thousands of taste receptors there are millions of odour receptors and there are many more odours than tastes.

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The olfactory epithelium is in the upper part of the nasal cavity above the turbinate bones. Smells reach the olfactory organs through the external nares, or from the posterior part of the mouth beyond the soft palate. Many substances are smelt after liberation by the warm atmosphere of the mouth. The olfactory organs occupy about 1 in^2 and consist of sensory nerve cells with processes extending to the free surface, supporting cells, basic cells and small serous glands (Bowman's glands) which contain a yellow-brown pigment. Pigmentation is not confined to Bowman's glands and is more intense in animals with a strong sense of smell. Each cell has twelve hairs which turn at right angles to the cell (Bloom, 1954). The receptors are bathed in mucus and are rendered insensitive when excessive mucus is present, as occurs with colds. The nerve fibre from each end-organ passes through the cribriform plate and connects with the olfactory bulb, the responses of which have been studied by Adrian (1956). In the olfactory bulb impulses stimulate many nerve cells which relay them to the hypothalamus and other parts of the brain. There are also nerve endings in the epithelium lining the lower part of the nose which are thought to react to pleasant as well as to repulsive odours, and whose fibres run into the fifth cranial nerve.

So far no satisfactory theory can be presented to explain olfaction. Many odoriferous substances are largely insoluble in water and it is not easy to understand how they stimulate the olfactory cells. The yellow pigment of the olfactory organs may be important (Allison, 1953; Kolmer, 1927). Beidler (1958) favours the theory that the reaction of the organ is similar to that of the ear. Sound is divided into its various frequencies and different auditory receptors respond to different frequencies. An odour might be analysed in a similar manner. Crocker divides odour into four sensations, namely the fragrant, sour, burnt and goaty sensations, and classifies each in strengths of 1–8. Vanilla is numbered 7122, i.e. seven fragrant, one sour, two burnt, and two goaty (Crocker, 1945).

Touch, heat, cold and pain are registered by nerve endings in the mouth and gums, and through the sensations of touch and pain the 'texture' of the food is perceived; consequently dentures must affect appreciation of texture. Food which is so rough or so hot in the mouth as to cause pain is said to have 'bite'. When the odour of a food causes pain in the nose it is said to have 'pungency'. The Chinese lay great stress on the texture of food. Sloppy overcooked cabbage is unappetizing. Steam-cooking and pressure-cooking tend to spoil texture. Gritty chocolate is not acceptable, but porridge, wholemeal bread and lentil soup must have roughness. Norwegian-type rye bread such as Ryvita must be spiky enough to cause pain. Saltiness is not registered at 85° so foods should be salted at body temperature. Foods stored in a refrigerator may be eaten at too low a temperature for full flavour.

Onions, garlic, spices and vinegar have bite and pungency. Pepper and ginger have bite but little pungency. Alcohol is hot in the mouth, menthol and peppermint are cold. Foods containing alkali, such as sea foods, and foods with enzymes, such as pineapple, dissolve the mucous membrane and cause slight injury, but it is soon healed. Mucus precipitation may give the astringent sensation of the tannins. The sensation of sodium glutamate may be tactile.

Chemistry

Salt is required to give flavour, particularly in cooked foods and cereals. The amount preferred may depend partly on the physiological requirements of the body, but normally it is just under 1%. Calcium chloride also has a salt taste. Sugar in all forms is an important source of flavour. In cooked foods much of it is in the invert state. Fructose is the sweetest, and lactose the least sweet, of the sugars. Scottish consumers like a sweeter product than English consumers; there are more sweet shops in Scotland than in England and in a test on South African grapes the Scottish choice was for a sweeter variety. The acceptable concentration of sugar depends on the food in which it is incorporated. Glycerine and liquorice are other sources of sweetness.

Acids found in food include acetic, propionic, butyric, tartaric, citric, malic, carbonic and phosphoric. Bitter substances are caffeine, theobromine, quinine and tannins. Hops, herbs and spices also supply bitterness and counteract too much sweetness or saltiness.

Caffeine is stimulating rather than flavorous. It is found in tea, coffee and cola drinks such as Coca-cola. The flavour in coffee has now been analysed. It is due to diacetyl, methylacetyl carbinol, furan, furfuraldehyde, furfuryl alcohol, acetaldehyde, pyridine and H_2S (Johnston & Frey, 1955). Woody flavours are added to various forms of alcohol by storage in oak barrels. Menthol has a peppermint flavour, acetaldehyde a sherry flavour, cinnamic aldehyde a cinnammon flavour, benzaldehyde an almond flavour and citral a lemon flavour. They give a slight pain sensation. Phenols give a numbing sensation: examples are clove oil and vanilla. Phenols are responsible for flavours in smoked products such as kippers.

Amino acids also subscribe to flavour. Sodium glutamate gives a flavour of chicken, methionine a rich flavour of cheese and, together with cysteine, a roasted flavour when heated. Leucine has a meaty flavour but a slightly musty odour. Glycine and alanine taste sweet.

The flavour of meat is not yet understood. It is volatile and is present in meat extracts, hence its loss in 'drip'. Breakdown products of muscle constituents may all be concerned. Diacetyl is largely responsible for the flavour of butter. Isothiocyanates contribute to the flavour of onions and cabbages, but the main flavour substance in onion is dipropylsulphide.

Much of the flavours in foods are in their aroma which is due to essential oils. Chemically these are not fats but mixtures of hydrocarbons, aldehydes, ethers and esters. They contain odourless impurities, terpenes, of which up to 90% tend to become oxidized to resins on exposure to air. The terpenes are often removed industrially and the oils stored as terpeneless oils. These lack complete natural flavour. The essential oils are present in special cells and may require enzymes to liberate them and even to convert them into flavorous substances. Many are highly volatile in steam, and steam escaping during cooking means loss of these oils. Celery and mushroom soup have little flavour if boiled hard. Steam cooking means loss of flavour for the same reason, and the steam trap contains a highly flavorous fat. In

https://doi.org/10.1079/PNS19610011 Published online by Cambridge University Press

experiments at this College, 'foil cooking' of meat, i.e. wrapping the meat in special foil before baking in the oven, gave a high flavour score. The cooking was at low temperature, and the flavour did not distill off. The methods of making jam cause distillation of much of the essential-oil content of the fruit. Essential oils are destroyed above 100°. Low-temperature distillation in vacuo of citrus juices gives a much better product, which has no objectionable cooked flavour. A high temperature spoils flavour. Essential oils can be collected in fat. This was an old-fashioned method of collecting scents—the enfleurage method. Chefs use it when they sweat vegetables in fat in the preparation of soups and sauces. Soups should not be skimmed completely free of fat since it contains much of the flavour.

Steam distillation can occur at any temperature if the moisture content of the atmosphere is low enough. It takes place in an ordinary refrigerator. The moisture condenses on the cold compartment, carrying with it the flavour of any uncovered foods. Foods containing fats should always be carefully wrapped, since they tend to absorb the flavour of other foods. Moist surfaces of foods can also absorb flavours.

Vanilla and parsley oils are less volatile than most essential oils; diacetyl, on the other hand, is very volatile. The main substance in a flavour may be easy to identify. In citrus oil 90% is limonene, but the supporting substance which gives the characteristic flavour may be only 5%, and is difficult to isolate. Flavorous substances may be present in extreme dilution, e.g. 1 in 40 million parts is the threshold value for diacetyl. Tons of material may be required to yield a few grams of the flavouring substance. There are substances in foods that can spoil desirable flavours. If these are removed flavours are more stable in canned foods and dehydrated products.

Many more methods are now available for the analysis of flavouring materials but, up to date, no flavour has been completely analysed. Many flavours are destroyed by heating but some are developed only by heat. This is true of coffee, cocoa and meat flavours. Tea is fermented to develop its flavour; tannin is destroyed by fermentation and bitterness removed. The flavour precursors in fruit have now been found to be resistant to heat, whereas the enzymes which develop them are destroyed (Hewitt, Mackay, Konigsbacher & Hasselstrom, 1956). Peroxidase and catalase, enzymes in vegetables, are destroyed by blanching in preparation for canning. If the right enzymes can be supplied it is possible to reproduce characteristic flavours from flavour precursors. This finding has been applied to some processed foods with considerable success. Unfortunately, flavour analysis when accomplished can only solve a small part of the problem. So many foods as eaten are mixtures of many ingredients, the flavours of which probably affect each other.

Laboratory flavour testing with panels

Panels must be carefully chosen. Members must be sensitive to flavours and have ability to remember flavours. Training is helpful, but it is difficult to know whether experience influences the judgement of panel members. A panel should never consist of less than five members, who must be healthy. Non-smokers are not essential provided no smoking is allowed for the hour before test. Tasting booths should be isolated and quiet and the member should be sitting and relaxed. Specimens tested must be of the same size and temperature. Better results are obtained by consulting a statistician before the test and designing the plan to suit the test. Only if such rules are observed can the panel method be regarded as a scientific instrument.

A description of various methods is given in *Flavour Research and Food Acceptance* (Peryam, 1958). When using these tests it must be remembered that there are people with a left-hand bias who always choose the left-hand object. 'Difference testing' is to find whether two products differ rather than to determine whether one product is better than another. The 'flavour profile test' (Cairncross & Sjöström, 1950) is a descriptive method. It describes the total effect or amplitude of a flavour, the factors which go to make it up, the strength of each and the order in which they are perceived. A panel of four is recommended, one being appointed leader. The panel perform several 'try-outs' and decide how the substance is to be presented. The test is then performed and is followed by a discussion. These sessions are repeated until the panel is in agreement. The leader then presents his report. The psychologists have criticized this test in that the leader may influence the opinion of other panel members, but it has been found to be highly effective.

'Ranking' is to rate a series of samples against each other as regards quality. It is a quick method, but if too many samples are included inconsistencies arise.

'Scoring' is to give a food a number according to its quality (Kramer, 1955). Scoring and ranking are used more than any other sensory tests. Consumer research has often been somewhat cynical about these scoring techniques. A product may score equally well with another product in a panel test and the public will buy 70% of the one and 30% of the other. It might be due to some slight difference in flavour, but advertizing weighs largely with the general public. Large-scale experiments must often be performed to test public opinion. We carried out just such a test on butter versus margarine in cakes, and found that the age group over 35 could distinguish the difference!

It is impossible to cover all the aspects of flavour, but the subject is well worthy of the attention of The Nutrition Society. Food must taste good if consumption is to be high. So much of our food must now be processed and it is important to maintain the flavour. Large-scale catering is extensive, and if the methods of cooking spoil the flavour of food they should be improved.

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The effects of industrialization, recent food legislation and advertising on food habits in Britain

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Industrialization could be expected to affect food habits in Britain in a number of ways. The substitution of mechanical power for muscular effort might reduce the demand for calories and hence change the kinds of food eaten and the nature and possibly the frequency of the meals taken. The increase in industrial productivity and the introduction of automatic processes and labour-saving devices would tend to save labour and reduce the hours of work, increase real wages and consequently improve the standard of living, which also might affect the kind of foods eaten. A third factor arising from industrialization, however, is that though the demands for muscular effort by the individual worker may be reduced, the call for increasing numbers of workers and particularly for more women becomes more insistent. Clearly the removal of women from the kitchen to the factory or office must exert a very direct effect on the food habits of the population.

At the same time as these influences are coming to bear on the population in an increasingly industrialized Britain, advances in food technology also bring about a change in eating habits. New developments in packaging and processing, canning, dehydration, the rapid advance in the technology of food freezing and the invention of entirely new foods all exert an influence in changing dietary habits. It is at this point that advertising has a part to play in popularizing newly developed foods.

The effect of changes in industrial work on food habits

Throughout the present century there has been an almost continuous reduction in the official working hours until today the standard working week is approaching 40 h. In a number of industries the 5-day week has also been adopted. Nevertheless no reliable information has been found about the total time actually worked and the number of people who work overtime on Sundays. Consequently, it has not been possible to estimate to what extent increasing industrialization is reducing maximum energy demands or, indeed, whether it is doing so at all.

The possibility that new automatic machinery may not in fact reduce the worker's energy demands and hence change the calorific value of his diet was shown by Scholz (1957–8) in Germany. In a study of men and women making medium weight castings in seven different foundries, he found that more than half the workers were